

Section 78-24-27-93-2

FLEXIBLE MEMBRANE LINER (FML)

02\93

\*\*\*\*\*

Includes Changes through Notice 4 (January 1997)

Latest Changes indicated by tokens

\*\*\*\*\*

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D 396	(1992) Fuel Oils
ASTM D 471	(1995) Rubber Property - Effect of Liquids
ASTM D 543	(1987) Standard Test Method for Resistance of Plastics to Chemicals
ASTM D 747	(1993) Apparent Bending Modulus of Plastics by Means of a Cantilever Beam
ASTM D 751	(1995) Coated Fabrics
ASTM D 2565	(1992a) Practice for Operating Xenon Arc-Type Light Exposure Apparatus With and Without Water for Exposure of Plastics
ASTM D 3389	(1994) Coated Fabric Abrasion Resistance (Rotary Platform, Double-Head Abrader)
ASTM E 96	(1995) Water Vapor Transmission of Materials

FEDERAL SPECIFICATIONS (FS)

FS VV-F-800	(Rev D; Am 2) Fuel Oil, Diesel
-------------	--------------------------------

MILITARY SPECIFICATIONS (MS)

MS MIL-G-3056	(Rev F; Int Am 3) Gasoline, Automotive, Combat
MS MIL-T-5624	(Rev P) Turbine Fuel, Aviation, Grades JP-4 and JP-5
MS MIL-T-38219	(Rev B; Am 1) Turbine Fuel, Low Volatility, JP-7
MS MIL-T-83133	(Rev D) Turbine Fuel, Aviation, Derosene

## 1.2 SYSTEM DESCRIPTION

This specification covers the requirements for a Flexible Membrane Liner (FML) system which is to be used beneath an aboveground vertical steel tank intended for storage of petroleum products.

## 1.3 SUBMITTALS

Government approval is required for submittals with a "GA" designation; submittals having an "FIO" designation are for information only. The following shall be submitted in accordance with Section 01300 SUBMITTAL DESCRIPTIONS:

### SD-01 Data

Manufacturer's Catalog Data; GA.

Manufacturer's standard catalog data giving the brand names and catalog numbers of all materials and the FML system in sufficient detail to demonstrate complete compliance with this section. Indicate the total number of job lots necessary to produce the total amount of FML required for the job.

Spare Parts Data; FIO.

Spare parts data for each different item of equipment specified, after approval of detail drawings and not later than [\_\_\_\_\_] months prior to the date of beneficial occupancy. The data shall include a complete list of parts and supplies, with current unit prices and source of supply, a recommended spare parts list for 1 year of operation, and a list of the parts recommended by the manufacturer to be replaced on a routine basis.

### SD-04 Drawings

FML Drawings; GA.

Detail drawings, prior to any fabrication or erection, which include as a minimum the FML layout plan with joint description, penetration detail, anchorage details, and installation instructions.

### SD-06 Instructions

Manufacturers Instructions; FIO.

The manufacturer's installation instructions and procedures for the FML and materials.

Framed Instructions; GA.

Framed instructions for posting, at least 2 weeks prior to construction completion.

### SD-07 Schedules

Tests; GA.

A letter, at least 10 working days in advance of each test, advising the

Contracting Officer of the test. A separate letter shall be submitted for each individual test.

Inspections; GA.

A letter, at least 5 working days in advance of each inspection, advising the Contracting Officer of the inspection. A separate letter shall be submitted for each individual inspection.

#### SD-08 Statements

Early Construction Statements; FIO.

A letter, prior to beginning any specified work, listing proposed testing equipment to be used throughout the project. The letter shall include calibration records for each piece of equipment.

Qualifications; GA.

A letter providing evidence of the Contractor's and the field engineer's experience, training, and licensing. Statements of previous FML job experience shall be provided with a POC, a phone number, address, the type of installation, and the current status of the installation.

Verification of Dimensions; FIO.

A letter stating the date the site was visited and a listing of all discrepancies found.

FML Manufacturer's Representative; FIO.

A letter, prior to placing the FML, from the FML manufacturer naming their authorized representative complete with their address, phone number, and a point of contact.

#### SD-09 Reports

FML Factory Test; GA.

[Six] [\_\_\_\_\_] copies of the information described below in a bound 8-1/2 by 11-inch booklet. Drawings shall be folded, with the title block visible, and placed in plastic pockets with reinforced holes. The FML factory tests shall be submitted and approved prior to the installation of any FML. Each section shall contain a detailed description of the test including:

- (1) A list of equipment used along with calibration certifications.
- (2) A copy of measurements taken.
- (3) The date of testing.
- (4) The parameters being verified.
- (5) The condition specified for the parameter.
- (6) The test results, signed and dated.
- (7) A description of adjustments made during the test.

Tests; GA.

[Six] [\_\_\_\_\_] copies of each test containing the information described below in a bound 8-1/2 by 11-inch booklet. Drawings shall be folded, with the title block visible, and placed in plastic pockets with reinforced holes.

- (1) A list of equipment used along with calibration certifications.
- (2) A copy of measurements taken.
- (3) The date of testing.
- (4) The parameters to be verified.
- (5) The condition specified for the parameter.
- (6) The test results, signed, dated, and certified by the field engineer. The certification shall state that required procedures were accomplished, that the procedures were conducted in compliance with the plans and specifications.
- (7) A description of adjustments performed.

Inspections; GA.

[Six] [\_\_\_\_\_] copies of each inspection containing the information described below in a bound 8-1/2 by 11-inch booklet. Drawings shall be folded, with the title block visible, and placed in plastic pockets with reinforced holes.

- (1) A list of equipment used along with calibration certifications.
- (2) A copy of measurements taken.
- (3) The date of inspection.
- (4) The parameters to be verified.
- (5) The condition specified for the parameter.
- (6) The inspection results, signed, dated, and certified by the field engineer. The certification shall state that required procedures were accomplished, that the procedures were conducted in compliance with the plans and specifications.
- (7) A description of adjustments performed.

SD-14 Samples

FML Samples; GA.

Samples, each tagged to identify:

- (1) Date the sample was taken.
- (2) Panel or sheet from which the sample was taken.
- (3) The location in the panel or sheet each sample was taken.

- (4) Who took the sample.
- (5) Any visual inspection comments.

Special Tools; GA.

One set of any special tools required for maintenance. Special tools are those that only the manufacturer can provide for special purposes such as reaching otherwise inaccessible parts. The tools shall be supplied complete with a suitable tool box.

SD-19, Operation and Maintenance Manuals

Maintenance Manual; GA.

[Six] [\_\_\_\_\_] copies of the information described below in bound 8-1/2 by 11-inch booklets which include a separate section for each of the following items.

- (1) Procedures for each routine maintenance item.
- (2) Procedures for troubleshooting.
- (3) Factory service manuals along with parts lists.
- (4) A reproducible copy of the framed instructions.

#### 1.4 QUALIFICATIONS

\*\*\*\*\*  
**NOTE: Include any local regulatory requirements  
that must be met by the Contractor.**  
\*\*\*\*\*

The Contractor shall meet the licensing requirements of the State in which the work is to be performed. The Contractor shall provide a field engineer full time to this project. The field engineer shall have successfully completed manufacturer's training for handling and installing FML systems as well as have at least one million square feet of installation experience.

#### 1.5 DELIVERY, STORAGE, AND HANDLING

Stored items shall be protected from the weather and contamination. Proper protection and care of all material before, during, and after installation is the Contractor's responsibility. Any materials found to be damaged shall be replaced at the Contractor's expense. The FML shall be stored in its original crates and if stored outdoors, the crates shall be placed on pallets and protected from the direct rays of the sun under a light-colored, heat-reflective, opaque cover in a manner that provides free-flowing air space between the crate and the cover.

#### 1.6 PROJECT/SITE CONDITIONS

##### 1.6.1 Verification of Dimensions

The Contractor shall become familiar with all details of the work, verify dimensions in the field, and advise the Contracting Officer of any problems before performing any work.

### 1.6.2 Testing and Flushing

Products (water, fuel, etc.) required for the testing and flushing of materials, equipment, instruments, personnel, supplies, etc. specified by this section shall be provided and disposed of by the Contractor.

## PART 2 PRODUCTS

### 2.1 STANDARD PRODUCTS

System components shall be environmentally suitable for the locations shown and be the manufacturer's standard as offered in catalogs for commercial or industrial use. Any non-standard product or component and the reason for its use shall be specifically identified by the Contractor in any required submittal.

### 2.2 NAMEPLATES

\*\*\*\*\*  
**NOTE: See Additional Note A.**  
\*\*\*\*\*

Nameplates shall be durable and legible throughout equipment life and made of [anodized aluminum] [stainless steel] [\_\_\_\_\_]. One plate shall be fixed to each tank in prominent locations. Each plate shall list the FML manufacturer's name, address, telephone number, point of contact, material type, model or serial number, catalog number, and authorized representative complete with a point of contact and their address and phone number.

### 2.3 MATERIALS

Components such as sleeves, boots, etc., shall be factory prefabricated from the FML material and have the same fabrication characteristics.

#### 2.3.1 Fuels

Materials, other than the FML, shall be resistant to the fuel or fuels being stored. Fuels as required or mentioned by this specification shall be in accordance with the following:

##### 2.3.1.1 Motor Gasoline (Mogas)

Mogas shall be in accordance with MS MIL-G-3056.

##### 2.3.1.2 Diesel

Diesel shall be in accordance with FS VV-F-800.

##### 2.3.1.3 No. 2 and No. 4 Fuel Oils

Oils shall be in accordance with ASTM D 396.

##### 2.3.1.4 JP-4 and JP-5

Fuels shall be in accordance with MS MIL-T-5624.

##### 2.3.1.5 JP-7

Fuel shall be in accordance with MS MIL-T-38219.

2.3.1.6 JP-8

Fuel shall be in accordance with MS MIL-T-83133.

2.3.1.7 ASTM Fuel B

ASTM Fuel B as referenced in this section shall be in accordance with ASTM D 471.

2.3.2 FML Ring Wall Sealant

The FML ring wall sealant shall be compatible with the FML, concrete, and the fuel being stored.

2.4 FLEXIBLE MEMBRANE LINER (FML)

\*\*\*\*\*  
**See Additional Note B.**  
\*\*\*\*\*

The FML shall demonstrate the acceptable limits of the properties listed under Table 1. The FML shall be factory produced from a base fabric that is completely covered with a polymer. The base fabric shall weigh no less than 13 ounces per square yard and be made of aramid (kevlar), polyester, or nylon. The FML shall have an overall finished weight no less than 30 ounces per square yard. Factory seams shall be made with a 2-inch overlap plus or minus 1/4-inch by an automatic thermal high-pressure welding process. The FML shall retard the growth of mildew and be capable of containing the liquid stored, withstanding temperatures up to 180 degrees F, withstanding humidity up to 99 percent relative humidity, and withstanding direct exposure to sunlight.

2.4.1 Job Lot of FML

A job lot of FML is defined by this specification as the amount of FML product that can be produced from a singular mixture of chemicals. Any FML material created from a new or altered mixture of chemicals shall be considered a new job lot.

2.4.2 FML Samples

Twenty four samples shall be cut from every job lot of FML. Each sample shall be approximately 8-1/2 inches by 11-inches in size. Eight of the samples shall be cut across factory seams.

2.4.3 FML Factory Test

Each manufacturer's job lot of FML shall have each of the FML properties verified by the factory test procedures and methods listed below. No substitute methods shall be allowed for verification of any property. Each separate verification of a property shall be made on a separate sample. The FML shall demonstrate through factory testing the acceptable limits of the following properties listed in Table 1. The properties shall be verified by each of the test standards listed.

TABLE 1. Standards and Limits for FML Properties

<u>Property</u>	<u>Acceptable Limits</u>	<u>Test Standard</u>	<u>Notes</u>
-----------------	------------------------------	--------------------------	--------------



TABLE 1. Standards and Limits for FML Properties

Property	Acceptable Limits	Test Standard	Notes
Minimum Overall Finished Thickness	32 mils	ASTM D 751	
Minimum Tear Strength (Fill)	40 pounds (ibd)	ASTM D 751 Tongue Method	(Warp &
Minimum Adhesion Strength	20 pounds per inch	ASTM D 751	
Minimum FML (MTS) (Fill)	1000 pounds (ibd)	ASTM D 751 Grab Method	(Warp &
Minimum FML (MTS) (Fill)	600 pounds (ibd)	ASTM D 751 Cut Strip Method	(Warp &
Minimum FML Seam Shear Strength	See Note 1	ASTM D 751 Section 53	
Minimum Abrasion Resistance	5,000 cycles	ASTM D 3389	See Note 2
Minimum Withstanding of Accelerated Weathering	1,000 hours	ASTM D 2565	See Note 3
Minimum Bursting Strength	1,500 pounds	ASTM D 751 Ball Tip Method	
Maximum Stiffness	30,000 pounds (ibd)	ASTM D 747	
Hydro Static Resistance	500 pounds per square inch	ASTM D 751	
Maximum Permeability	0.10 ounces per square foot per 24 hours	ASTM E 96 Procedure BW	See Note 4
Fuel Compatibility	No Delamination, No Bubbles, No Discoloration	See Note 5	
Maximum Volume Swell (Coating Compound Only)	15 percent of original	See Note 6	
Maximum Weight Gain or Loss	10 percent of original	See Note 5	

## Table Abbreviations:

(ibd) in both directions (MTS) Material Tensile Strength

## Notes:

1. The acceptable limit for the seam shear strength shall be 95 percent of

the minimum (MTS) property using the Strip Method.

2. Test until fabric exposure with an H-22 wheel loaded to 1,000 grams.

3. Manufacturer's certification of the FML, instead of actual factory testing, may be considered acceptable for the Minimum Withstanding of Accelerated Weathering if the certification verifies that the acceptable limits listed were previously achieved using the test standard listed.

Data from either a manufacturer's certification or an actual factory test shall verify that no visible cracking or appreciable changes resulted as a result of the testing.

4. The test shall be performed using the Inverted Water Method with ASTM Fuel B.

5. Testing shall be performed in accordance with ASTM D 543 by immersion in ASTM Fuel B for 14 continuous days at room temperature.

6. Testing shall be performed in accordance with ASTM D 471.

#### PART 3 EXECUTION

##### 3.1 FIELD ENGINEER

The field engineer shall supervise the complete installation of the FML and perform each FML inspection and test.

##### 3.2 PREPARATION

Prior to laying out the FML, three sample field seams shall be performed. Each seam shall be 5 feet in length. Seams shall be made only when the ambient temperature and the temperature of the FML are both 25 degrees F or higher.

##### 3.3 INSTALLATION

Parts subject to degradation or requiring adjustment, inspection or repair shall be accessible and capable of convenient removal.

###### 3.3.1 Surface Preparation

The surfaces to be covered shall be free of vegetation, rocks, debris, etc., graded true, compacted, and be smooth with no abrupt projections of any kind.

###### 3.3.2 FML Installation

After successful completion of the FML visual inspection, the FML shall be laid out. Laying out and welding FML shall only be done when the ambient temperature and the temperature of the FML are both 25 degrees F or higher.

Field seams shall have a 2-inch overlap plus or minus 1/4-inch, and be made by the FML manufacturer's authorized representative. Panels or sheets of FML to be seam welded together shall be laid out prior to welding field seams. The overlapped areas shall be cleaned and prepared according to the installation instructions and procedures. Welds shall be tightly bonded.

###### 3.3.3 Framed Instructions

Framed instructions shall include equipment layout, wiring and control diagrams, piping, valves, control sequences, and typed condensed operation instructions. The condensed operation instructions shall include preventative maintenance procedures, methods of checking the system for normal and safe operation, and procedures for safely starting and stopping the system. The framed instructions shall be framed under glass or laminated plastic and be posted where directed by the Contracting Officer.

The framed instructions shall be posted before acceptance testing of the system.

### 3.4 TESTS

#### 3.4.1 FML Vacuum Box Test

After successful completion of the FML visual inspection, a vacuum box test shall be performed on all field seams, the area around the seams, and all FML surfaces showing injury due to scuffing, penetration by foreign objects, or distress from rough subgrade. A glass topped vacuum box which has a neoprene sealing gasket shall be used. The vacuum box test shall be performed as follows:

- (1) A commercial bubble forming solution shall be applied to the area to be tested.
- (2) The vacuum box shall be positioned over the area and a vacuum slowly applied until a differential pressure of 1 pound per square inch is achieved and held for at least 5 seconds while observing the solution for bubble formation.
- (3) If the vacuum box test indicates a continuous stream of bubbles on repeated testing at the same location, then the area being tested shall be considered damaged and shall be repaired and retested.
- (4) If the vacuum box test do not indicate a leak, then the vacuum shall be slowly increased until a maximum differential pressure of 2 plus 0.0 or minus 0.25 pounds per square inch is achieved and held for at least 20 seconds. If the test indicates a continuous stream of bubbles on repeated testing at the same location, then the area being tested shall be considered damaged and shall be repaired and retested. Care must be taken to limit the vacuum to no more than the maximum differential pressure because, if it is exceeded by more than 0.25 psi the FML shall be considered damaged and shall be replaced and retested.

#### 3.4.2 FML Air Lance Tests

After successful completion of the FML vacuum box test, an air lance test shall be performed on all seams not accessible with a vacuum box test (i.e. small seams around penetrations, oddball types of patches, etc.). The air lance test will be performed using a 50 psig jet of air regulated and directed through a 3/16-inch diameter nozzle, applied to the upper edge of an overlapped seam or repaired area to detect an unbonded area. Inflation of any section of the seam by the impinging air stream shall be indicative of an unbonded area. Unbonded areas shall be repaired and retested.

### 3.5 INSPECTIONS

#### 3.5.1 Sample Field Seam Inspection

##### 3.5.1.1 Visual Inspection

Sample field seams shall be subjected to a visual inspection performed within 30 hours after the seam has been made, cured, and cooled.

##### 3.5.1.2 Vacuum Box Inspection

After successful completion of the visual inspection, a vacuum box

inspection shall be performed. A glass topped vacuum box which has a neoprene sealing gasket shall be used. The vacuum box test shall be performed as follows:

- (1) A commercial bubble forming solution shall be applied to the area to be tested.
- (2) The vacuum box shall be positioned over the area and a vacuum slowly applied until a differential pressure of 1 pound per square inch is achieved and held for at least 5 seconds while observing the solution for bubble formation.
- (3) If the vacuum box test indicates a continuous stream of bubbles on repeated testing at the same location, then the area being tested shall be considered damaged and shall be repaired and retested.
- (4) If the vacuum box test do not indicate a leak, then the vacuum shall be slowly increased until a maximum differential pressure of 2 plus 0.0 or minus 0.25 pounds per square inch is achieved and held for at least 20 seconds. If the test indicates a continuous stream of bubbles on repeated testing at the same location, then the area being tested shall be considered damaged and shall be repaired and retested. Care must be taken to limit the vacuum to no more than the maximum differential pressure because, if it is exceeded by more than 0.25 psi the FML shall be considered damaged and shall be replaced and retested.

#### 3.5.2 FML Initial Inspection

A visual inspection of the FML shall be performed on each FML panel or sheet as it is unrolled. The Contracting Officer shall be notified of any visually detected damage. The visual inspection shall also verify the finished surface to be covered with the FML is properly graded and compacted.

#### 3.5.3 FML Seam Inspection

Field seams shall be subjected to a visual inspection performed within 30 hours after the seam has been made, cured, and cooled. Any seams visually found to be defective shall be repaired and reinspected.

#### 3.5.4 Acceptance Inspection

As soon as practicable after successful completion of the FML vacuum box test and the air lance tests, an acceptance inspection shall be performed. If the inspection reveals any defects in the work, such defects shall be repaired or the unsatisfactory work replaced before acceptance. The cost of such repairs and replacements shall be borne by the Contractor. The Contractor shall provide materials, facilities, and equipment necessary to permit adequate inspection by the Contracting Officer or his representative.

#### 3.6 MANUFACTURERS FIELD SERVICE

If any problems are noticed in any inspection of a seam, the Contracting Officer shall be notified immediately. The FML manufacturer's point of contact shall also be contacted by telephone and informed that the installation of their product can not be adequately completed. After a solution has been formed, jointly between the FML manufacturer and their authorized representative, as to why the problems were encountered, another set of sample field seams shall be made and reinspected.

\*\*\*\*\*

ADDITIONAL NOTE

NOTE A: In a salt water environment substitute acceptable non-corroding metal such as but not limited to nickel-copper, Type 304 stainless steel, or monel. Aluminum is unacceptable. Nomenclature (or system identification) to be established by designer.

NOTE B: The products listed below are considered to meet this specification as of December 1991.

Petroguard 10 sold by MPC Containment Systems, Ltd.,  
4834 South Oakley, Chicago IL 60609, POC Ed Reicin,  
800-621-0146, 312-927-4120.

L3284NESU made by Cooley, Inc., 50 Esten Ave,  
Pawtucket, RI 02860, POC Steve Seiner, 800-333-3048,  
401-724-9000

Style 1642 PTF MS-400 made by Seaman Corporation,  
216-262-1111, 800-321-2615, 1000 Venture Blvd.,  
Wooster Ohio 44691, POC Felon Wilson Knoxville, TN  
615-691-9476

\*\*\*\*\*

--End of Section--